METHOD AND DEVICE FOR RECOGNIZING
VISUAL OBSTRUCTIONS IN IMAGE SENSOR SYSTEMS

Background Information

The present invention relates to a method and to a device for
recognizing visual obstructions in image sensor systems.

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In the future, in particular in conjunction with environmental
sensing of motor vehicles, image sensors such as video
cameras, for example, will be used whose image is evaluated by
downstream functions (driver assistance functions, for

10   example). It is therefore of particular importance to
recognize visual obstructions which degrade the image detected
by the image sensor, to inform the downstream functions or
systems of the presence of such visual obstructions, and to
initiate countermeasures if necessary.

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Advantages of the Invention

The detection of the blurriness of the recorded image results
in a suitable procedure which assists in recognizing visual

20   obstructions. It is particularly advantageous that downstream
systems or functions, which function properly only when the
view is adequate, are informed of the presence of the visual
obstruction and are thus able to initiate suitable
countermeasures. When a visual obstruction is recognized,

25   depending on the design of the downstream function or system
the recorded image is advantageously not evaluated or
corrected, or other suitable measures, such as switching on
the windshield wiper system or windshield heating, for
example, are performed.

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It is particularly advantageous that visual obstructions are recognized based on the image signal itself, so that no additional sensors are necessary.

5   The procedure is suitable in particular for recognizing a visual obstruction on the windshield of the motor vehicle.

The image sensor advantageously takes over additional functions, such as the function of a rain sensor, for example,
10   so that this rain sensor may be dispensed with in the furnishing of the vehicle with such image sensor-based driver assistance functions, for example lane monitoring systems.

The procedure described below is used in a particularly
15   advantageous manner in video sensor systems in motor vehicles which are not focused on the vehicle windshield, but rather on the external region. The procedure described below may thus be used to particular advantage in conjunction with the sensing of the environment around a motor vehicle. In this manner the
20   image sensor may be used for multiple applications (for example, rain sensor and object detection, etc.).

It is also advantageous that the image sensor is able to check its functionality using its own output signal, i.e., to
25   determine whether the instantaneous view conditions are sufficient for the next function that is to be performed. When the image sensor is not functioning properly, this is advantageously signaled to the driver or the downstream system, and/or countermeasures are taken.
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It has been shown in a particularly advantageous manner that the detection of visual obstructions is performed by measuring the blurriness of the represented image. A reliable method is thus provided for determining visual obstructions, in
35   particular objects on a vehicle windshield, which appear blurry in the image. It is particularly advantageous that

transparent objects such as raindrops, or semitransparent objects such as ice or dust, for example, are recognized, and in one particular embodiment even distinguished from one another, by measuring the blurriness of the image.

Thus, it is also advantageously possible to obtain information about the type of visual obstructions. In this manner a response specific to the particular type of visual obstruction may be made, for example by automatically switching on the windshield washer system when the windshield is soiled by particles.

Further advantages arise from the following description of exemplary embodiments and the dependent claims.

Drawing

The present invention is explained in greater detail below with reference to the exemplary embodiments illustrated in the drawing.

Figure 1   shows an overview illustration of an image sensor
                system in which the procedure described below for
                determining visual obstructions is implemented;
                and

Figures 2
through 4   show diagrams with reference to which three
                different embodiments for determining the
                blurriness in the image and the recognition of
                visual obstructions derived therefrom are
                described.

Description of the Exemplary Embodiments

The image sensor system illustrated in Figure 1 is composed

essentially of an optical sensor array which is connected to a
data processing unit 7, for example a microprocessor. The
instantaneously visible scene is mapped onto the sensor array
by a lens system 2. The image sensor is mounted behind a

5   windshield 1 and is focused on the external region behind the
windshield. The windshield is, for example, the window glass
of a vehicle, in particular the windshield of the vehicle. The
focusing on the vehicle's external region allows the image
sensor system to also be used for other image processing

10   operations such as lane detection or obstruction detection,
for example. Evaluation unit 7 is composed of a module 4 for
controlling lighting of the sensor array, a measuring unit 5
for estimating blurriness, and a decision module 6 which makes
decisions regarding the presence and, optionally, the type, of

15   a visual obstruction. In one preferred embodiment all of these
modules are part of a microprocessor, the modules being
implemented as software programs. In other embodiments, the
modules are individual components (processors), likewise
implemented as software, where estimations of blurriness are

20   made, for example, in one component and decisions are made in
another component. The decision made by decision module 6 is
then relayed as an information and/or activation signal to
downstream functions and/or systems. Application possibilities
are described in greater detail below.

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The automatic detection of visual obstructions on the
windshields of a vehicle therefore plays an increasingly
important role due to the fact that, when image sensors are
used in the vehicle, systems which evaluate the images from

30   the sensor function properly only when the view is adequate.
If there is information about the visual obstruction and, in
the ideal case, about the type of visual obstruction, such a
system is able to display to the driver its instantaneous lack
of functionality and/or to take countermeasures, such as

35   switching on the wiper system, windshield heating, windshield
washer system, for example.

When visual obstructions are determined based solely on the image sensor signal, the problem arises that visual obstructions on a vehicle windshield are made noticeable in the image only indirectly, since for use in driver assistance

5 systems the image sensor is focused on the vehicle's external region. Objects on the windshield, for example raindrops or dust, are therefore blurrily imaged. These visual obstructions are thus made noticeable by a characteristic distribution of the blurriness in the image signal.

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The detection of visual obstructions is based on measuring the blurriness of the image which is recorded by an image sensor. This blurriness is made noticeable by a lack of sharpness of the imaged contours of the instantaneously visible scene.

15 Objects present on the windshield are blurrily imaged due to the focusing of the image sensor on the external region. Transparent objects, such as raindrops, for example, result in localized defocusing of the image, and semitransparent objects such as ice or dust scatter incident light beams. Both effects

20 result in an increase in the blurriness of the sensor signal. The evaluation unit which is associated with the image sensor, an optical sensor array of, for example, a CCD or CMOS camera, detects the distribution of blurriness of the instantaneously imaged scene. Based on the detected distribution of

25 blurriness, a conclusion is drawn as to the presence of a visual obstruction. One of the methods for digital image processing described below is used for determining the blurriness.

30 In one preferred embodiment, the image sensor is a sensor array which assists in obtaining information also on the type of visual obstruction. This fundamentally distinguishes such a sensor array from a conventional rain sensor which operates by the reflection principle. The use of a sensor array allows a

35 specific response to be initiated to the determined visual obstruction, for example, by additionally switching on a

windshield washer system for soiling caused by particles. One
preferred procedure for recognizing the type of visual
obstruction is likewise described in detail below.

5   A first possibility for measuring blurriness is illustrated
with reference to the diagrams in Figure 2. Blurriness is
measured here using the contrast spectrum. The underlying
principle of this method is known from the field of digital
image processing. To obtain the contact spectrum, first a

10   multiscale analysis is carried out in which the video image is
decomposed into multiple images of decreasing resolution by
the repeated use of a smoothing operation and subsequent
subsampling. A global measure of contrast, for example the
standard deviation of the intensity values in the image, is

15   calculated in each resolution stage. The measure of contrast
plotted as a function of the resolution forms the contrast
spectrum of the image. Examples of such contrast spectra are
shown in Figures 2a and 2b. In these figures, the particular
measure of contrast K of the image is plotted as a function of

20   resolution A. Sharp and blurry images differ in their contrast
spectra by the fact that the drop in contrast as a function of
increasing resolution is steeper in blurry images than in
sharp images. This is because fine details are degraded more
strongly by visual obstructions than are coarse image

25   features. Thus, the drop in the contrast spectrum is a measure
of the blurriness of the image. Situations are shown as
examples in Figures 2a and 2b. Figure 2a illustrates a
contrast spectrum as a function of the image resolution for an
image with slight blurriness, while Figure 2b shows the

30   situation for high image blurriness (blurry image).

In one implementation of the procedure for determining the
blurriness of the image, the contrast spectrum is recorded by
multiscale analysis within a computing program, and a variable

35   is determined, for example the average increase in the measure
of contrast as a function of the resolution, which

characterizes the variation of the measure of contrast as a
function of the resolution. The blurriness of the image is
determined by comparing this variable to at least one limiting
value. For recognizing a visual obstruction, in particular

5   with regard to the response measures planned in the downstream
systems, it is sufficient to determine that the image is
blurry; thus, the determined variable is compared to a
limiting value, and if this limiting value is exceeded,
blurriness may be assumed, or the variable itself is relayed

10   as a measure of blurriness. In other applications, determining
a measure of the blurriness is desired. In these cases,
limiting values form ranges for the variable which
characterizes the contrast spectrum and to which blurriness
values are assigned. A value for the magnitude of the

15   blurriness is determined when the value characterizing the
contrast spectrum is in a specified range of values.

In addition to measuring the blurriness by using the contrast
spectrum, there are a number of other methods from the field

20   of digital image processing that may be used to detect
blurriness. Examples of such alternative methods for measuring
the image blurriness are measures for analyzing the Fourier
spectrum or the autocorrelation of the analyzed image. In the
Fourier spectrum a blurry image is characterized by the fact

25   that the amplitudes of the high spatial frequencies, which
represent the finer image details, are strongly attenuated in
comparison to a sharp image.

Examples of such a situation are shown in Figures 3a and 3b.

30   The curve of the Fourier spectrum is plotted in both figures,
the amplitude of the Fourier transformation function being
represented by the spatial frequency. Figure 3a shows a
slightly blurry image, while Figure 3b shows a highly blurry
image. It is obvious that the amplitudes at the higher spatial

35   frequency decrease greatly for a blurry image. For evaluation,
in one preferred embodiment it is therefore provided that the

amplitude and the corresponding spatial frequency are used to
recognize values that fall below a threshold value. If this
spatial frequency is below a predetermined value, it is
assumed that the image is blurry. In another embodiment, the
slope of the curve could also be used here to determine
blurriness by comparing it to at least one limiting value. For
the evaluation of the Fourier spectrum as well, it is possible
to determine a value for the magnitude of blurriness by
specifying multiple limiting values or by specifying value
ranges, and relaying this value to downstream systems.

A third possibility for measuring blurriness is the
autocorrelation function of the image. This autocorrelation
function decreases less steeply for a blurry image than for a
sharp image as a function of distance. This is because only
large structures remain in a blurry image. Figure 4
illustrates this relationship, the particular magnitude of the
autocorrelation function being plotted as a function of the
pixel separation. Figure 4a shows the autocorrelation function
for a slightly blurry image, and Figure 4b shows the
autocorrelation function for a highly blurry image. The
figures show that as the pixel spacing for an image having a
low degree of blurriness (sharp image) increases, the
autocorrelation function rapidly decreases, whereas for a
blurry image the decrease in the autocorrelation function is
less. As indicated above, for the evaluation it is possible to
use at least one limiting value or multiple limiting values
being exceeded or not being attained, or, in another
embodiment, to use the calculated average increase to
determine the blurriness and/or to determine a value for the
magnitude of the blurriness.

A further alternative for measuring blurriness is provided by
an indirect classification formulation in which a learning
machine, a neural network or a polynomial classifier, for
example, is trained to distinguish between blurry and sharp

images by presenting a large number of images as examples.

As mentioned above, a visual obstruction is assumed when a high degree of blurriness is recognized, or the value of the blurriness is greater than a predetermined value. In addition, a comparison to reference distributions for contrasts, Fourier components, or autocorrelations may differentiate various types of visual obstructions based on their similarity to specific reference distributions. In this manner it is possible to distinguish moisture on the windshield from ice or dust on the windshield, and, depending on the situation, to initiate different countermeasures, for example, activation of the windshield wiper, switching on a windshield heating system or a windshield washer system, etc. Here as well, the above-referenced classification formulation may be provided by learning machines.

If the video sensor having visual obstruction detection is also operated as a rain sensor, further additions are useful. If moisture on the windshield is recognized based on the determined blurriness and the contrast distribution, or the Fourier spectrum or autocorrelation, the windshield wiper is, as previously, initially actuated only at the explicit request of the driver, to prevent erroneous start-up when an error is detected. Using the video images which are recorded immediately after the wiping operation, it is possible to obtain the above-mentioned reference distributions, using which a decision is made to initiate the next wiping operation. Thus, the wiping response may be adapted on a situation-specific basis. For situations in which the surrounding scene contains too little contrast, it may be practical to temporarily switch on a windshield light. Visual obstructions are then detectable from the scattering of the light.